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CHOOSING BETWEEN DIFFERENT EDM MACHINES

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ABSTRACT: Electrical discharge machining is one of the most studied nonconventional technologies. Research in the field is extremely numerous and the use of electrical erosion machines is very widespread. Most often, when purchasing an electrical erosion machine, only the machine's price and the productivity are considered. The paper shows that there are many more factors that should be taken into account, and therefore sometimes it is necessary to perform a multi-criteria analyse to decide on the "perfect" machine. The criteria are chosen by each user, depending on the momentary and perspective needs.
KEYWORDS: EDM, machines, multi-criteria analyse

1. INTRODUCTION

The demand for EDM machines has grown in recent decades, both because of harder materials and because of particularly complex shapes that can be manufactured by this technology. The major disadvantages of these equipment were the low productivity, the high tool wear and the instability of the process. Because of this, research in the last decade focused on finding viable solutions to solve these problems [1, 2, 3]. The research areas studied in the last few years can be summarized as per figure 1.

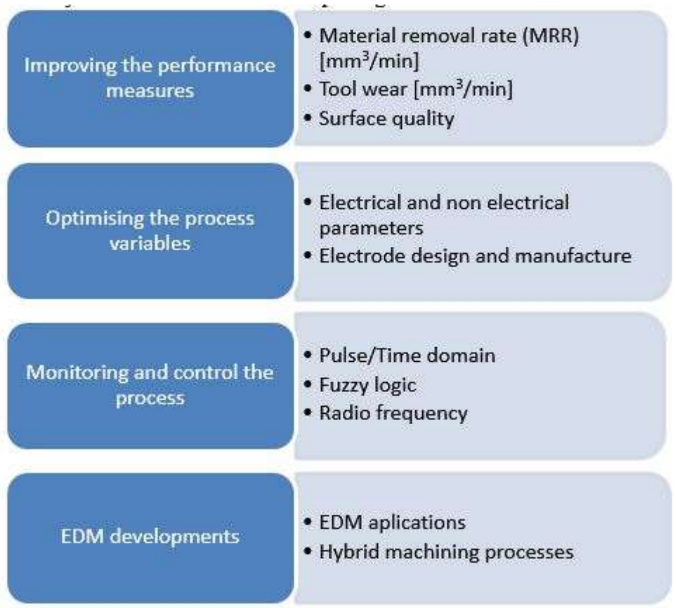

Figure 1. Research areas

A part of these researches has been put into practice, so that the new equipment is capable of performing much better than old ones.

The trends of miniaturization and the use of very hard materials with very complex shapes, are poised to spur demand for EDM. The research report "Electrical Discharge Machines: A Global Strategic Business Report" realized by Global Industry Analysts Inc. [4], provides a comprehensive review of market trends, drivers, challenges, mergers, acquisitions and other strategic corporate activities of major players worldwide. It is provided by 2024 the EDM global market will reach $ 7.5B. 36 key players covered in the report include AA EDM CORP., AccuteX EDM, Beaumont Machine, CHMER EDM, Chevalier Machinery Inc., Excetek Technology Co. Ltd., GF Machining Solutions, Kent Industrial USA Inc., Knuth Machine Tools USA Inc., Makino Milling Machine Co. Ltd., MC Machinery Systems INC, ONA Electroerosion S.A., and Sodick Inc., among others (5 from Europe, 6 from United States, 13 from Asia without Japan and 7 from Japan).

As one can see, there are many EDM producers, and of course, everyone produces more types of machines. For example, when opening the site of Charmilles, the main page presents a range of 12 ram sinking EDM machines (figure 2), 10 wire EDM, one drilling EDM and a few old EDM machines. In this context, it is very hard for a buyer to appreciate with machine is the best solution for him.

Figure 2. EDM machines [5]

Usually, an EDM machine is constituted by a part that assures the support and displacement of the workpiece and the electrode, a power supply, a dielectric tank with a dielectric circulation and filtration equipment and a programming unit, as one can see in figure 2. Modern machines may have many special features which assist and improve the machine operation.

Figure 3. EDM machine (adapted after [6])

In [2] it was made a classification of EDM processing machines according to performance measures, machining capacity and auxiliary facilities. The classification is briefly presented in table 1.

Table 1. A classification of EDM machines (adapted from [2])

Performance measures	Accuracy	
	Surface finish	
	Filtering size	
	Erosion rate	
	Working current	
Machining capacity	Structure	C type
		Gantry type
	Working envelope	
	Axis	3 axes
		4 axes
		6 axes
		8 axes
	Maximum workpiece size	
	Maximum workpiece weight	
	Orbiting	Fixed
		Programable
Auxiliary facilities	Automatic tool changer	
	Electrode weight	
	Tank	Fixed type
		Drop type

Under these circumstances, choosing the most appropriate machine for an enterprise can be a pretty difficult task. It is necessary to perform a detailed analysis and this paper presents a multi-criteria analysis that can be realized.

2. THE MULTI-CRITERIA ANALYSE

Performing such a multi-criteria analysis imposes unequivocal determination of the evaluation criteria. These criteria must be independent and of course, as relevant as possible for the case.

The criteria to be considered can be determined taking into account the advantages and disadvantages of this type of processing. As is known from the specialty literature, the advantages of electric erosion processing are [7, 8]:

- the possibility of processing complex forms, difficult or impossible to obtain by other processes;
- The ability to process hard materials and very precise dimensions;
- processing of very small parts, whose integrity could be affected by classical processing;
- processing very small holes
- a very good surface roughness

On the other hand, the disadvantages of this type of machining are:

- low MRR;
- additional time and costs for the tools manufacturing;
- specific power consumption very high;
- excessive tool wear;
- high power consumption.

A comparison (table 2) between the EDM process and other unconventional processes reveal the weaknesses of the method.

Table 2. Comparison of unconventional processes

Process	Capital cost	Tooling cost	Power cost	MRR efficiency	Tool wear
EDM	**M**	**H**	**L**	**H**	**H**
USM	L	L	L	H	M
AJM	VL	L	L	H	L
ECM	VH	M	M	L	VL
CHM	M	L	H	M	VL
EBM	H	L	L	VH	VL
LBM	L	L	VL	VH	VL
PAM	VL	L	VL	VL	VL

In the table there are the following notations:

- USM – ultrasonic machining
- AJM – abrasive jet machining
- ECM – electrochemical machining
- CHM – chemical milling
- EBM – electron beam machining
- LBM – laser beam machining
- PAM – plasma arc machining

From the table no. 2 one can see that in comparison with other processes, EDM has as disadvantages the high tooling cost and the high tool wear. Both the two disadvantages can be partially removed by using a CNC machine eventually with a C axis ore even an orbiting movement.

It is known that in EDM the requirements for a tool long life are contrary to those of a high productivity or a reduced energy consumption [9].

That is why the author consider that it is a good choice to have in attention a criterion with includes the tool wear, maybe in relation with productivity.

In [10] is presented a study of the costs of some micro-EDM processing. The total cost is divided in 2 components: a fixed one, which includes ownership and routine maintenance, and a variable one, which includes labour cost, extraordinarily maintenance, utilities costs, tool and workpiece. The first part of the paper presents a mathematical model and then the model is validated by experimental researches made with different pieces and different tools. The results are presented in the form of graphs that give the variation of the different costs according to the concrete conditions. By interpreting graphical results and calculating the cost of electrode wear, we have concluded that only electrode wear has a share of 10-15% of variable costs. This percent is varying with many concrete conditions [11], but it gives us an image of how important is to keep in mind, when buying a machine, the aspects that are related to the reduction of electrode wear. That is why we propose a criterion named "specific productivity" which is defined as the ratio between processing productivity and tool wear. If the tool wear is not very important, we can use instead the tool wear, the energy consumption, which also increases with the productivity.

After analysing several aspects regarding the EDM equipment, the author proposed the criteria shown in figure 3.

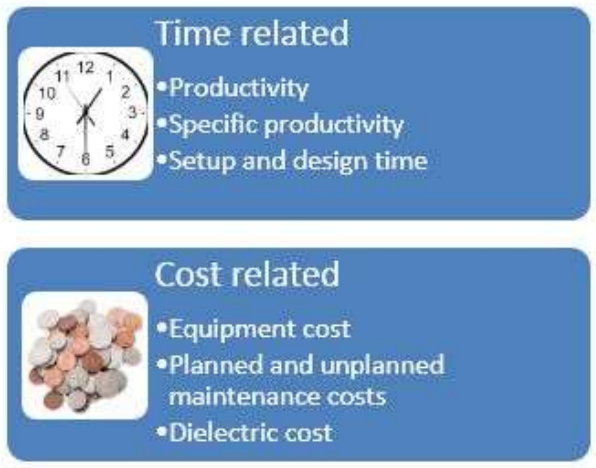

Figure 4. Criteria for the analyse

Notice that the precision of processing isn't a criterion, because it is self-evident that the chosen machine must accomplish it. Sometimes even the machine cost isn't a criterion in this analyse because the price of the chosen equipment is really similar to that of the other options.

The author consider that the planned maintenance cost can be, sometimes, large enough - especially when special instruments for wear monitoring are provided - so it is important to take it into consideration as a criterion. If it isn't important to apply a predictive maintenance, then this criterion may be ignored, or it is possibly noted with a low grade.

It is necessary to determine the importance of the criteria related to the enterprise needs.

It is important to specify what special features we need, and how important this/these is/are for the product. The list of special features is very long as many EDM machines producers have developed different features. A list may include:

- C- axis;
- Tool charger;
- monitoring and adapting devices;
- adaptive generator;
- dielectric cooler;
- permanent magnetic table;
- high speed turbo magnetic circuit;
- robot connection;
- programming on a personal computer and simply download on the machine
- integrated robotics
- intelligent power generator technology…

Because there is a link between the added features and the price of the machine, the author considered that the two criteria are dependent and therefore it is not recommended to take the feature as a criterion. Obvious the features influence both productivity and the rest of the indicators that characterize the processing.

In order to determine the weight of a criteria, a table will be drawn, that will serve to prioritize the criteria. The criteria will be compared to each other and the result of the comparison will be assigned to the following score: if two criteria are equally important, each gets 0.5 points; if one criterion is more important than another, the most important one receives 1 point and the least important receives 0 points.

Following this rule, each criterion will add a certain number of points. The criterion that has the most points is on the 1st place, the others following in descending order of the score. If 2 criteria have the same number of points, they will occupy the place calculated as the arithmetic mean between their two places (for example, if there are 2 criteria that would occupy 3rd and 4th place, they will be both in the 3,5rd place). With this data, one will compute the weight of each criterion with the "Frisco" empirical formula

$$\delta_i = \frac{p+\Delta p+m+0,5}{-\Delta p'+\frac{N_{crt}}{2}} \quad (1)$$

where: p is the sum of the points obtained on the line for the specific criteria;

Δp - the difference between the score of the considered element and the one from the last place;

m - the number of outclassed criteria;

Δp' - the difference between the score of the considered element and the one from the top place;

Ncrt - number of criteria.

After studying the models that meet most of the basic demands, one can choose between selected machines considering previously established criteria. Every model will be rated with notes from 1 to 10, in relation witch each criterion (note 10 is the best).

After that, a weighted average is calculated for each model. The machine with the highest weighted average is the better choice for the enterprise.

3. CASE STUDY

One enterprise from Sibiu, Romania, decided to buy a new EDM machine for machining a piece like the one in figure 4.

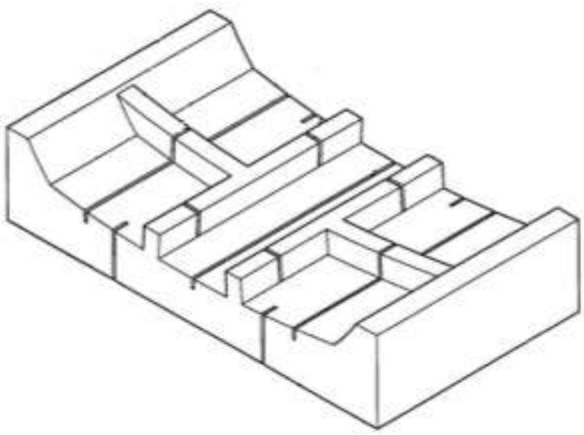

Figure 5. Example of workpiece

After studying the market of EDM machines, the head of the acquisition department decided that there are 3 models which are appropriate when it comes to assured accuracy and of equipment cost.

The choice was made between three options. A multicriterial analyse was made based upon the following criteria:

- the productivity of the machine in the case of the pieces that will be produced P
- the specific productivity as a report between the P productivity and the energy consumption (having in mind that EDM is a process that consumes a lot of energy) PS
- planned maintenance cost MP
- setup and design time SDT

The costumer considered that from the four criteria, P and PS have the same importance, SDT being the next and MP the less important criterion. In these circumstances, the Table 2 was built.

Table 3. Calculating the weight of the criteria

	P	PS	SDT	MD	Σ points	Position	Weight
P	0.5	0.5	1	1	3	1.5	4
PS	0.5	0.5	1	1	3	1.5	4
SDT	0	0	0.5	1	1.5	3	1.14
MD	0	0	0	0.5	0.5	4	0.22

Tables 3, 4 and 5 analyse the three alternatives in terms of weights and grades of the four criteria opposite. On the fourth column there is the result obtained by multiplying the weight (the second column) with the note (the fourth column).

Table 4. Calculation for machine no. 1

Criterion	Weight	Machine no. 1	
		Note	Weight note
P	4	10	40
PS	4	8	32
SDT	1.14	8	9.12
MD	0.22	9	1.98
			83.1:4=20.775

Table 5. Calculation for machine no. 2

Criterion	Weight	Machine no. 2	
		Note	Weight note
P	4	9	36
PS	4	9	36
SDT	1.14	9	10,26
MD	0.22	10	2.2
			84.46:4=21.115

Table 6. Calculation for machine no. 3

Criterion	Weight	Machine no. 3	
		Note	Weight note
P	4	10	40
PS	4	8	32
SDT	1.14	9	10.26
MD	0.22	8	1.76
			84.02:4=21.005

As one can see, the model no. 2 has the highest score, so that it is the best choice for the costumer. The second choice is the machine no. 3 and the third choice is machine no. 1.

To see the differences that may appear if one has another need and consider the same criteria but with other importance, we will analyse the case when the criterion P is the most important, the PS criterion is as important as SDT and MD is the less important.

In this case the table with calculate the weight is the table no. 7 and the 3 tables for the weight note are tables no. 8, 9 and 10.

Table 7. Calculating the weight of the criteria

	P	PS	SDT	MD	Σ points	Position	Weight
P	0.5	1	1	1	3.5	1	5.5
PS	0	0.5	0.5	1	2	2.5	2
SDT	0	0.5	0.5	1	2	2.5	2
MD	0	0	0	0.5	0.5	4	0.22

Table 8. Calculation for machine no. 1

Criterion	Weight	Machine no. 1	
		Note	Weight note
P	5.5	10	55
PS	2	8	16
SDT	2	8	16
MD	0.22	9	1.98
			88.98:4=22.245

Table 9. Calculation for machine no. 2

Criterion	Weight	Machine no. 2	
		Note	Weight note
P	5.5	9	49.5
PS	2	9	18
SDT	2	9	18
MD	0.22	10	2.2
			87.7:4=21.925

Table 10. Calculation for machine no. 3

Criterion	Weight	Machine no. 3	
		Note	Weight note
P	5.5	10	55
PS	2	8	16
SDT	2	9	18
MD	0.22	8	1.76
			90.76:4=22.69

As one can see, in this situation machine no. 3 is now on the first place, after that is machine no. 1 and on the last place is the second machine. The examples show how important it is to correctly rank the criteria.

4. CONCLUSIONS

The paper shows that it is important to consider many criteria, besides price, accuracy and supplementary features, when it comes to buy a EDM machine. A multicriteria analyse is properly for this situation, but it is very important to correctly establish the criteria, the relative importance of each criterion and obvious, how well meets each machine the criteria.

The calculation it's very simply but people who sets the criteria must be well prepared and have to know very good the needs of the enterprise. It is necessary to have the support of the seller for noting the machines in relation with the criteria, otherwise the result can be inappropriately with the real need. Small changes in criteria hierarchy or in giving marks can significantly change the final rankings.

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